ARMY RESEARCH LABORATORY

Low-Echelon Command and Control for Fire Support: The SMART FO Program

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13. ABSTRACT *(Maximum 200 words)*

During March - April 1993, the U.S. Army Research Laboratory (ARL) conducted a series of successful field tests to determine the feasibility of attacking a moving target with indirect artillery fire. The tests involved an M109 howitzer with an on-board ballistic computer, and a forward observer (FO) equipped with a laser range finder and a laptop computer. The forward observer's computer provides the capability for the observer to input a target path, update the position of the moving target along the path, predict the position of the target along the path, and predict fall-of-shot. The computer program, named SMART FO, has the flexibility to change the target path during mission execution, receive observer location from Global Positioning System (GPS) input, and laser data from the Ground/Vehicular Laser Locator Designator (G/VLLD). This report describes the SMART FO program, its user-interface, the mission sequence of the moving target mission, and field test results of the March - April 1993 testing program. The use of a semiautomated howitzer with the SMART FO program provides the field artillery with effective moving target engagement capability, which provides tactical advantages for small-unit, low-intensity conflicts as well as major military compaigns.

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1. INTRODUCTION

The coordinated attack of moving targets by indirect fire–support is a time–consuming and inexact process. The current mission sequence requires a forward observer (FO), equipped with a laser range finder, a paper map, and a compass, to estimate the location of a moving a target. Time lines for these missions exceed 200 s to initiate, and there are no support tools for the observer that allow for the accurate prediction of the target's position [1]. The mission sequence requires the FO to send laser range finder data to a Fire Direction Center (FDC), which computes a straight–line prediction of the target in the future. The FDC computes an intercept point and a time–to–impact of the rounds at the intercept point. The FDC then sends the firing command to the howitzer, with the appropriate time–to–fire. At the designated time–to–fire, the howitzer fires the mission. This mission flow would work if moving targets traveled in straight lines for long periods of time (3 min or more) [1], but in the real–world this does not happen. The solution to this problem is to give the mission control tools to the person in contact with the target, the FO, allowing him to direct the fall–of–shot and the time of impact. The tactical experience of the FO gives him a good sense of how the target might maneuver based on the terrain and conditions along the target path, and providing the FO computer support to track the target, anticipate its path, update its movement along a route, predict fall–of–shot, and send fire commands to the howitzer would improve the time line of the mission, decrease the error of the fall–of–shot, and increase the rate–of–fire on the target. The computer support system to accomplish this, the Smart FO, puts this computer power into the hands of the FO.

The SMART FO program has a color digital map of the terrain. It has a communications subsystem to send and receive digital messages, Global Positioning System (GPS) position data, and laser range finder data. The software includes data entry dialog screens for all Digital Message Device (DMD) messages for transmission and reception, a subscriber table, and data default data entry screens.

The SMART FO program was designed to provide the user with the flexibility and data necessary to efficiently execute the current task. Fire missions are executed using mission screens. These screens have been tailored for the unique characteristics of each type of fire mission. For example, the Fire–For–Effect mission contains controls to initiate and end the mission. The Adjust Fire mission, however, contains controls to initiate the mission, perform adjustments, enter a Fire–For–Effect phase, and end the mission.

This report discusses the current DMD message format and moving target mission sequence, and then the SMART FO missions. The SMART FO user–interface and the efficiency improvement it provides to the user are discussed. The SMART FO program screens are described in detail in the Appendix.

2. CURRENT DIGITAL MESSAGE DEVICE USER INTERFACE

The input device used by today's FO is the DMD. This device has been in service since the early 1980s, is ruggedized for field use, is compact, and is lightweight. The display is a plasma display, and currently has limited graphics support. Information is displayed to the user in the form of text messages, which closely resemble the digital message format used for communications between DMDs. Figure 1 shows a DMD screen for the FRLASER message (taken from TM 11–7025–244–12&P [2]), used to start a fire mission.

```
FR LASER    D        FILE 1                  AUTH:?
DIR: ?                       STR :N/G       ANGLE: LO
SLT DIST: ?                  DOP: N/G        PRI: 2
VA: ?                        RAD/LGTH: N/G
                                                OB: 00
MSN: STA TGT
TGT: N/G                     SHELL/FZ: NO PREF
     ,                       CONTROL: ADJ FIRE
TGT NO:                      VOLLEYS:
   DEST : : : :
AUTO TGT NO: OFF
(XMIT, += RETURN,C=CONV)                 00 : 00 : 00
```

Figure 1: DMD FRLASER

The user is required to enter all data necessary for fire mission initiation and execution by pressing menu selections and textual information on the keypad or by lasing the target. The DMD FRLASER message format has the advantage of validating data entry at the field level but does not support multiple tasks such as data–entry and received message review. The user–interface has lights on the left side to alert the user when a message has been received, but this gives him no indication of the message type or priority. Mission–essential data are buried within the message text. The interface does not allow for the insertion of vehicle paths or mission sequence timing. This simple display cannot support the monitoring function required for moving target missions, and as a result the field artillery does not attempt the mission. The task for the March–April 1993 test was to develop a user–interface which would provide the mission monitoring functionality required for the moving target mission and also support the message creation functionality like the current display. In addition, the program must fit into a package of comparable size and weight to the currently fielded system.

3. SMART FO PROGRAM DESCRIPTION

The Smart FO program consists of a color digital map, a communications program, and a program executive which configures the system and executes the finite–state machine for mission execution. The software architecture is shown in Figure 2.

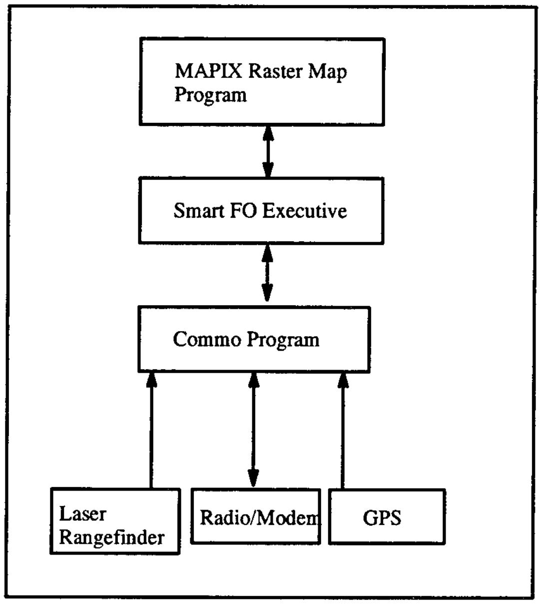

Figure 2: Smart FO Software Architecture

The color digital map is used to display known friendly and enemy positions and track targets. The digital map includes functions to support the input of routes, waypoints, and areas. The digital map used, MAPIX, developed by Hyperdyne, Inc. of Vienna, VA, includes an interface language to query and update information from an external program using the Microsoft Windows Dynamic Data Exchange (DDE) for Interprocess Communications (IPC). Using the MAPIX Control Language, the executive program could add and delete objects and receive MAPIX updates on changes made to its display by the user such as the addition/modification/deletion of a route or area. The use of MAPIX in the user–interface allows the user to visualize and verify the computer track with ground truth, see fall–of–shots as they occurred, and see computed fall–of–shot locations.

The communications program receives, decodes, and forwards all messages received from the serial ports. The serial ports can be configured to receive data from a GPS receiver, a laser range finder, and radio modems. In addition, the communications program initializes the multichannel communications board. The communications program receives messages to be transmitted to the serial ports from the executive program via the DDE IPC mechanism, and messages received from the serial ports are formatted and sent to the executive program using DDE.

The executive program runs the missions. The executive program displays dialog boxes, which the user uses to input data required for a mission function. The executive program keeps track of moving targets by running a dead–reckoning algorithm to update their movements. Targets can be updated in two ways. The first is straight–line prediction, with the speed determined by laser range finder data. The second is route–following, with speed determined by laser range finder data, and the route determined from user input to the digital map. Figure 3 shows the user–interface main window.

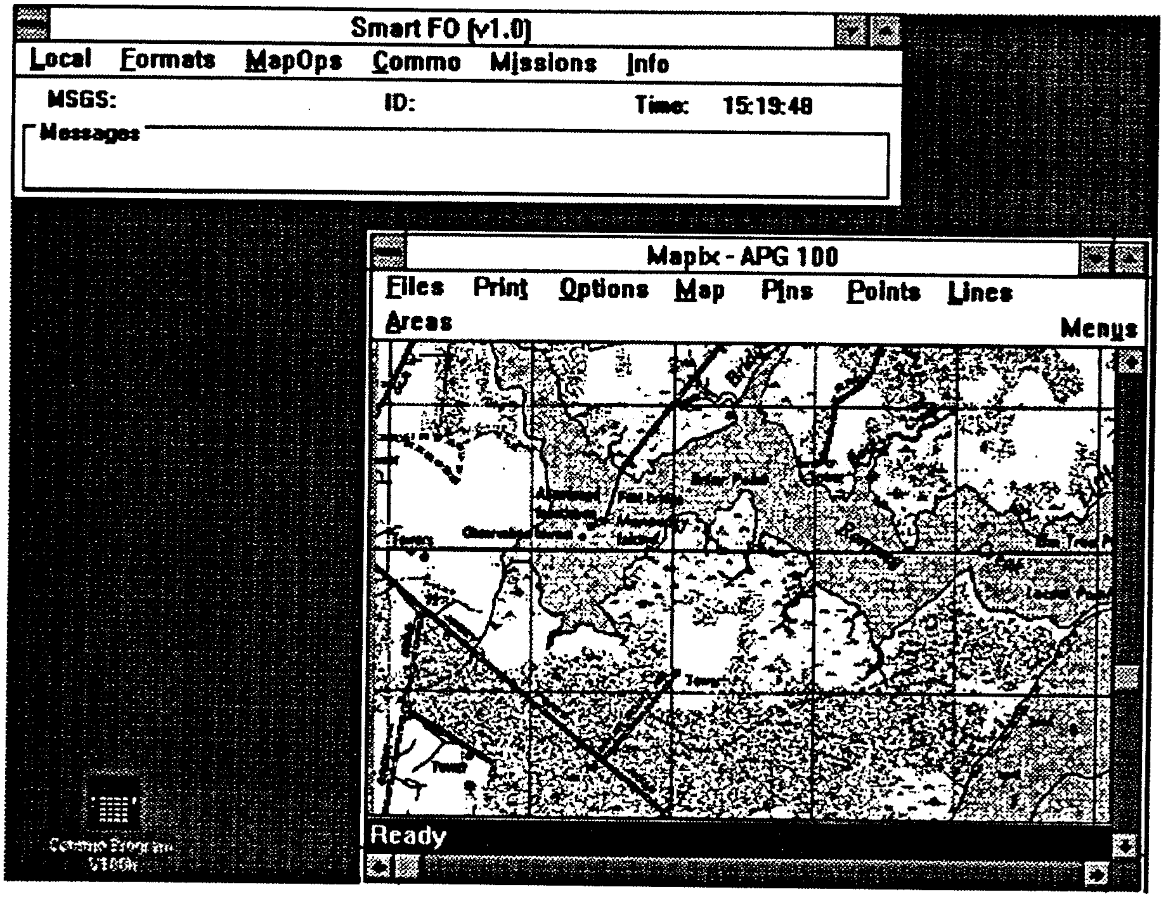

Figure 3: Smart FO Main Display

3.1 Data Fusion

The FO was equipped with a laser range finder, an Army Standard FM radio, a radio/modem, and a lunchbox IBM–PC compatible 386 computer running Microsoft Windows 3.1. Data processed by the program included GPS position reports, laser range finder data, and communications from the radio.

3.2 Laser Range Finder

The laser range finder used is the Ground/Vehicular Laser Locator Designator (G/VLLD). This laser is in current use by the field artillery to get range and azimuth information to targets and landmarks. The laser has a digital output port which outputs laser data in a digital format.

3.3 Global Positioning System (GPS)

The GPS receiver used in the Smart FO is a Trimble TANS receiver. The receiver outputs the latitude and longitude of the receiver in the WGS–84 world coordinate datum. In the field tests, the receiver was set to output data at a rate of 1 data report every 2 s.

3.4 Radio/Modem

A mini–Tactical Communications Modem, developed by Magnavox, was used to send and receive messages from the PC to the radio.

4. SMART FO USER INTERFACE

The user–interface of the Smart FO is a Microsoft Windows–based GUI. The interface is characterized by pop–up dialog boxes, called Mission Windows, which encapsulate all mission–essential information in one window. The interface was designed based on how the soldier fights, not on how to create messages. Therefore, message format windows do not appear in the Smart FO. All 21 DMD messages can be formatted and transmitted, but none is presented while running a fire mission. Figures 4 and 5 show mission windows for the Adjust Fire and Moving Target missions, respectively.

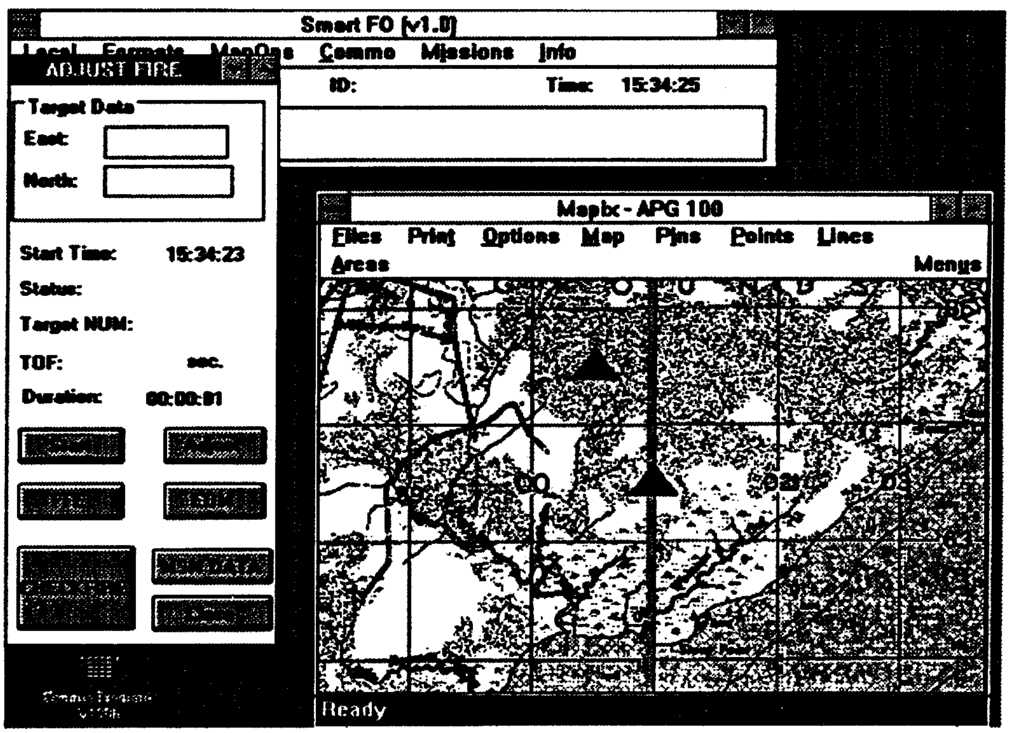

Figure 4: Adjust Fire Mission Window

4.1 Adjust Fire Mission

The Adjust Fire mission is prosecuted in four phases. Phase 1 is the initial call for fire, with the target location providing the coordinates for the fall of shot. Phase 2 is the adjust phase. During this phase, the FO moves the fall–of–shot location to account for errors between the fall–of–shot location sent

to the howitzer, and where the rounds actually landed. This phase can last from one to three adjustments. Phase 3 is the Fire–For–Effect phase. During this phase, the howitzers fire on the location last received for the required number of rounds. Phase 4 is the End–Of–Mission, with the FO sending target disposition information to the howitzer as a damage assessment.

Current DMD message screens require the user to initiate two separate message screens for this mission, the FRLASER to start Phase 1, and the SALASER to conduct phases 2, 3, and 4. The message screens contain all the required information for the mission, including redundant information. For example, target description, munition information, and communications parameters such as origination and destination addresses do not change during a mission.

The Smart FO interface presents all the information required for the conduct of the mission in the mission window. The user can set target description and munition information by bringing up a Message Defaults dialog by pressing MSN DATA. These data are used to format messages to be transmitted to the howitzer. Mission control information is implied by the mission phase, and the Smart FO software automatically fills this in the message before transmission. In addition, the FO can "lase" the fall of shot with the laser, which displays a square icon on the map display. Using this information, the FO can adjust the next round based on the error of the fall–of–shot. In addition to entering target information with the laser, the FO can enter target locations directly by clicking on the map. The location is fed to the mission window, and a fire mission can be started on this location. This capability provides the observer with the capability to preplan target locations, by saving them into a target file. In addition, the point–and–click paradigm is good for accuracy, as the pixel resolution of the map display is 10 m.

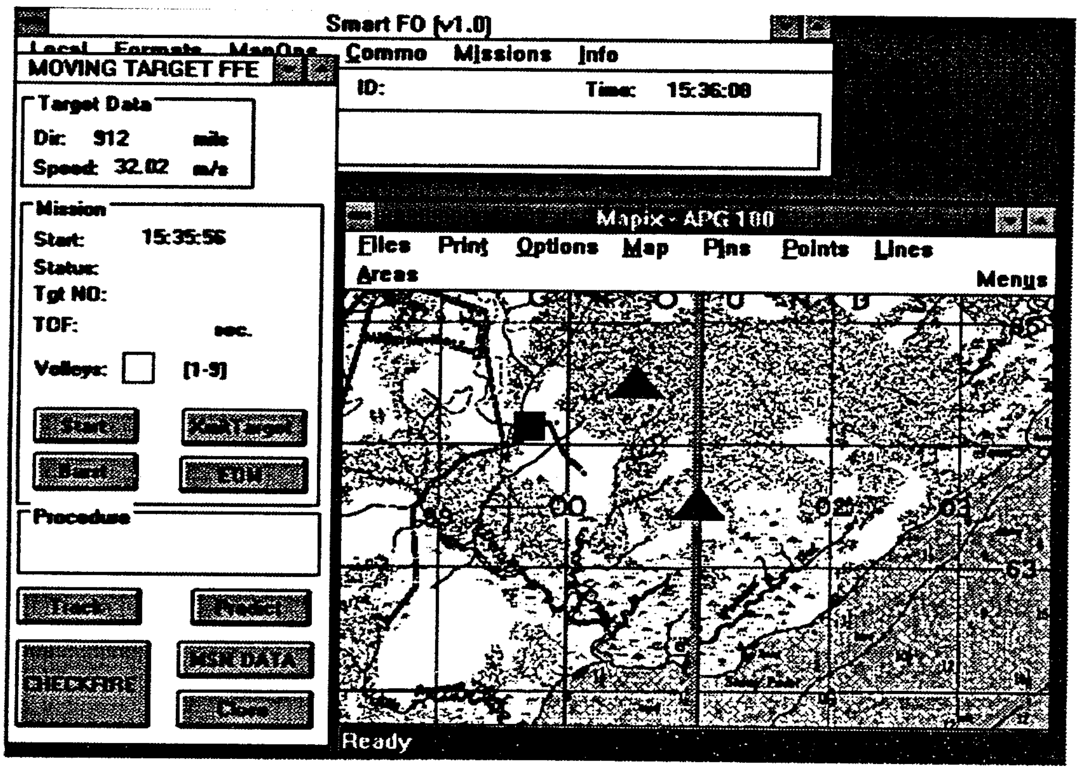

Figure 5: Moving Target Mission Window

4.2 Moving Target Mission Procedure

The moving target mission procedure used in the field tests is an algorithm developed for the purpose of testing the effectiveness of FO control of moving target missions with an autonomous howitzer. The howitzer was equipped with a special fire control computer which processed messages from the Smart FO. The mission flow is shown in Figure 6.

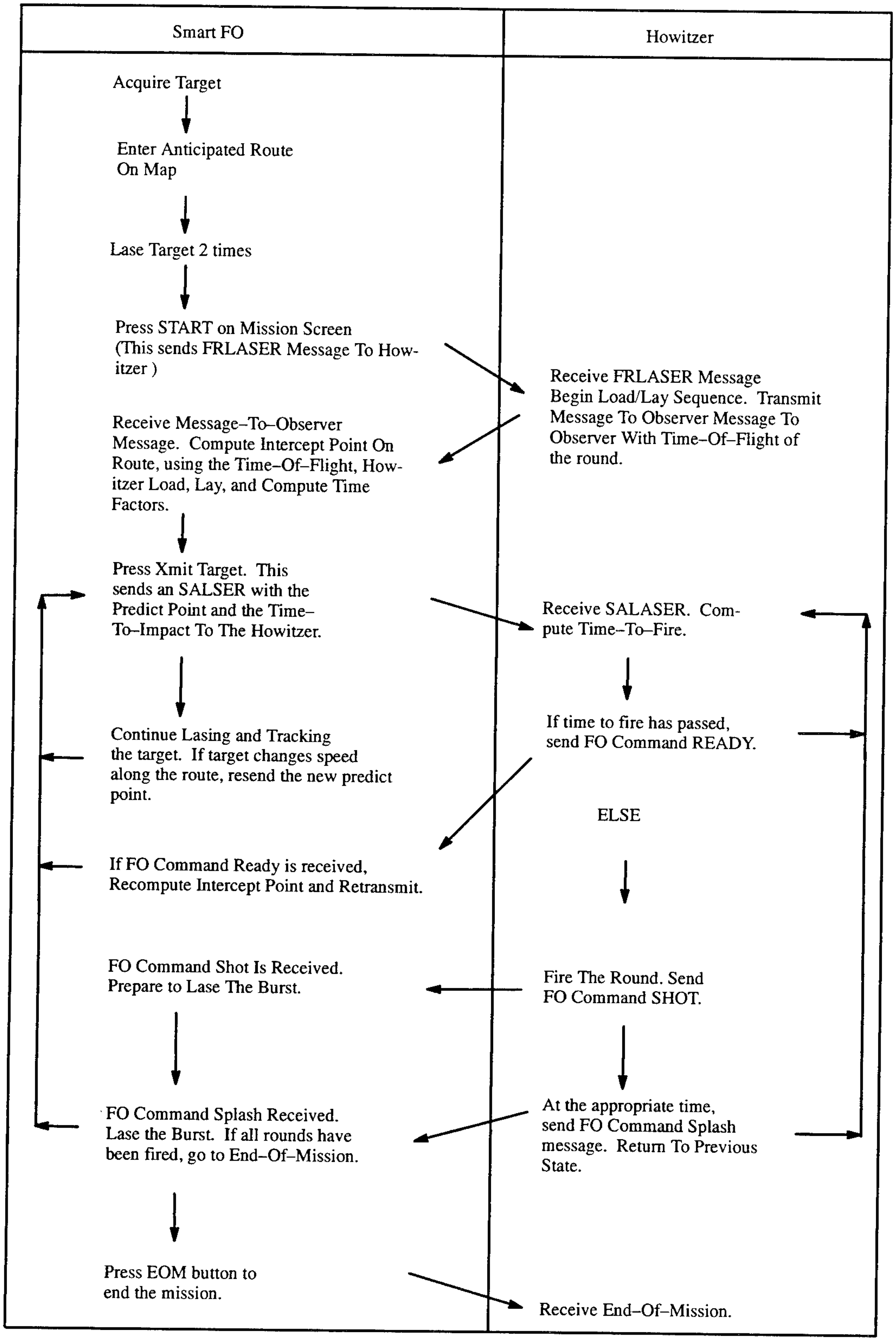

Figure 6 : Moving Target Mission Algorithm

As shown by Figure 6, the moving target algorithm requires strict sequencing and timing for the mission to process smoothly. In addition, the FO and howitzer are performing tasks in parallel, which reduces mission processing time by allowing the FO to prepare the next intercept point while the howitzer is in the process of firing the current one. The event–driven algorithm is easily programmed using a state–engine, with state transitions occurring upon receipt of a mission message. The state engine of the Smart FO has three states: wait for message to observer (MTO), wait for shot (SHOT), and wait for splash (SPLASH). State MTO is set when the user presses START. Pressing START creates a Predict Point Icon to be displayed on the digital map. This Icon will move, based on the speed of the vehicle and the lead–time set for dead–reckoning computations. This state allows the user to update the target track on the map based on the latest lasings, but does not allow the user to send a message to the howitzer. State SHOT is entered when the MTO message is received. This state allows the FO to send intercept points to the howitzer by pressing the Xmit Target button, in addition to updating the target track of the target from lasings. The Predict Point Icon will snap to a recomputed intercept point, based on the Time–Of–Flight of the munition, as received in the Message–To–Observer message. When the user presses the Xmit Target button, the Predict Point Icon will be fixed at its current location. Ideally, the target icon and the Predict Point Icon will be colocated at the time of round impact. When an FO Command SHOT message is received, the state engine transitions to SPLASH. This state prompts the user to prepare the Burst and starts a countdown clock, which is displayed in the Procedure window. When the FO Command SPLASH message is received, the engine transitions to state SHOT, and the Predict Point Icon begins moving on the map. At anytime during state SPLASH, the user may press the Predict button, which will reset the state engine to state SHOT. This escape provides a manual state change in the event an FO Command SPLASH message is not received due to communications problems.

The user–interface of the Smart FO hides these details from the user. The user wants to know two things — where the target is, and how good the predictions are. The digital map shows the user where the target and predict points are, the lasings are plotted using an X icon for verification of lasings, and the fall–of–shot verifies the predict points. The mission window displays target lasing data, including the target's speed. The user–interface of the Smart FO takes the guesswork out of the moving target mission, in addition to hiding the complexity of the procedure. The user is required to keep his map updated by lasing the target, and pressing the Start, Xmit Target, Burst, and EOM buttons to control the mission.

5. FIELD TEST RESULTS

The Smart FO was used in March–April 1993 in an evaluation of the British AS–90 howitzer [3]. As a part of the evaluation, the moving target mission was performed. The Smart FO was operated by the author, and a coworker operated the laser range finder. Using the aforementioned hardware and software, 26 moving target missions were performed. Of these, 16 missions containing 42 rounds were analyzed. A total of 14 rounds were judged to directly affect the target, with an additional 24 rounds falling within 500 m, with the majority within 200 m. To be effective, a round must be judged to land within 50 m of the moving target. Of the 16 missions analyzed, mission times ranged from a low of 61 s to a high of 224 s from time of mission start to time of round impact. Table 1 shows the results of the moving target missions [3].

Missions Analyzed	16
Rounds Analyzed	42
Rounds Affecting Target	14
Rounds Within 500 m Of Target	24
Mission Times Seconds (Low/High)	61/224

Table 1: Field Test Summary

6. CONCLUSION

The Graphical User–Interface of the Smart FO program is a powerful interface design for the monitoring and control of finite state machines. The mouse–driven interface allows the user to successfully execute the moving target mission, a mission not performed using current user–interfaces and protocols, with a minimum of keystrokes. The dialog–style mission windows encapsulate all mission–critical data and event messages into an easily readable form, with the necessary controls to monitor mission status and reset the state–machine to a known state in the event of missed mission events. The task analysis used to develop the state–machine resulted in an efficient, event–driven application which is fault–tolerant and modular.

The development environment used not only aided in the rapid development of the dialog mission windows, but aided in the development of modular software that is easily modified when adding new functionality.

7. REFERENCES

1. Headquarters, Department Of The Army. Field Manual FM 6–30, Tactics, Techniques, and Procedures for Observed Fire. 5–23 — 5–25, 16 July 1991.

2. Headquarters, Department Of The Army. Training Manual TM 11–7025–244–12&P, Technical Manual, Operator's And Organizational Maintenance Manual, Digital Message Device AN/PSG–5 (Fire Support Team). 1 November 1994.

3. Tauson, R., Dousa, W., & Zubal, O. (1995). Foreign Material Exploitation Of The British AS–90 Self–Propelled 155mm Howitzer. ARL Report (Pending).

APPENDIX A:

SMART FO USER INTERFACE

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A–1. INTRODUCTION

This appendix explains the user–interface of the SMART FO. The screens are shown and explained.

A–2. SMART FO Main Window

The main window of the SMART FO program is the starting point for all operations. The program executive, SMART FO, the digital map, MAPIX, and the commo program are visible in this picture. These programs are executed simultaneously and share data using Interprocess Communications. This allows multiple operations to occur at the same time. For example, the commo program receives laser data and radio communications at the same time the program executive is updating the target track on the MAPIX display.

The user uses the mouse to select options in the menu bar of the program executive and MAPIX. The user must make sure the time display on the program executive and the howitzer ballistic computer are synchronized, or mission timing will not be correct. Time is set from a DOS window using the TIME command.

The program is initialized automatically upon startup.

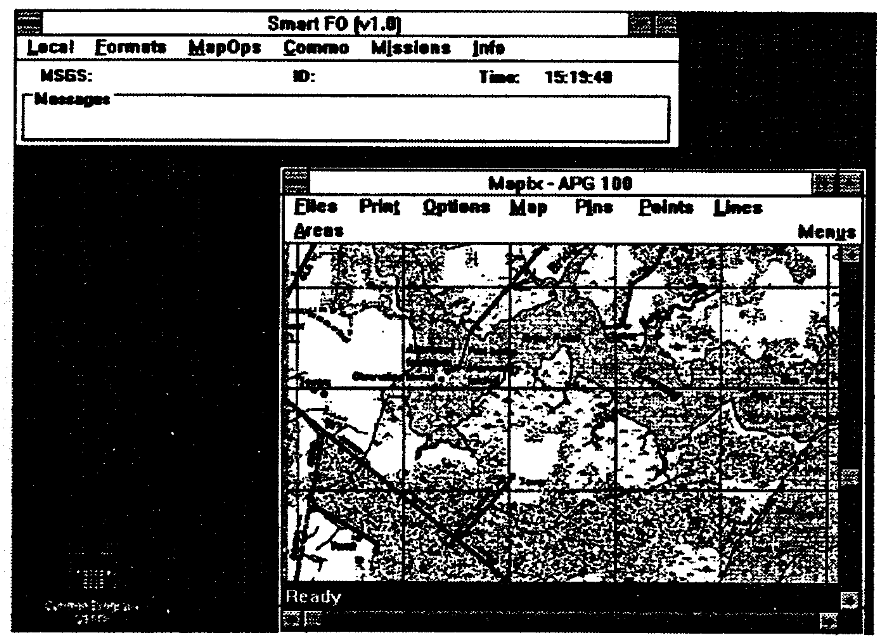

Figure A–1: SMART FO Main Window

A–3. Local Device Setup

Figure A–2 shows the local menu choices. This allows the user to set local parameters such as communications address, Fire Support Center address, local name, observer number, location, and GLLDCO; send an observer location (OBSLOC) message to the FIST; select the GPS device to use; and orient the laser.

Figure A–3 shows the Local Data dialog. Enter data as appropriate. An Observer Location message can be sent to the FIST by pressing the OBSLOC button.

Figure A–4 shows the GPS setup dialog box. Select the GPS receiver type in use by clicking the left mouse button on the appropriate Check–Box. The update spacing will send an OBSLOC message to the FIST when the observer's GPS location has moved more than the update spacing amount. This is useful for times when the observer is moving.

Figure A–5 shows the Laser Orient dialog. This option allows the observer to orient the laser using the digital map. To perform this operation, click on the map to an easily identifiable landmark. The position will be entered in the Map Data field. Now lase the landmark with the laser. The laser data will be displayed in the Laser Data field. The Procedure field prompts the user for the operation to perform. Alternately, the user can lase to a previously surveyed point to orient the laser. Using this option assures the user that the program is receiving laser data properly.

The user should review the information in the local setup upon program initiation. This ensures that the observer's position is correct, digital message parameters are set up, and the laser is surveyed in.

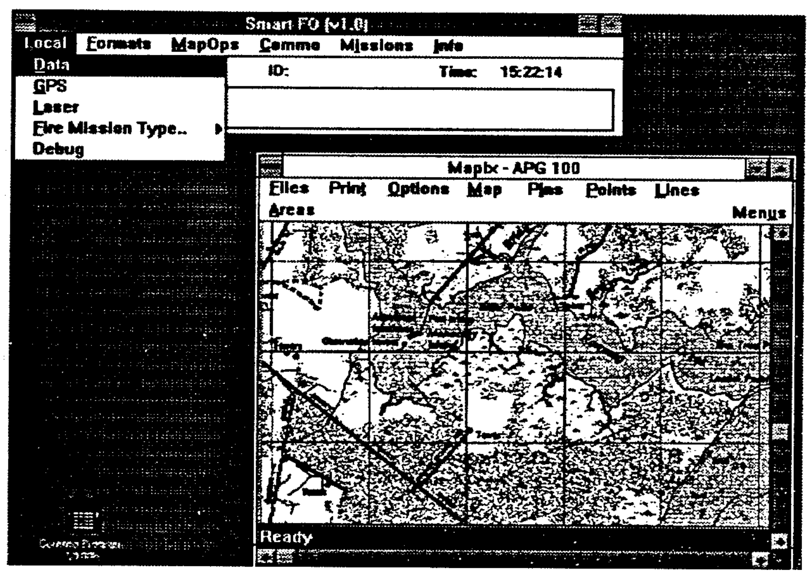

Figure A–2: SMART FO Local Data Menu

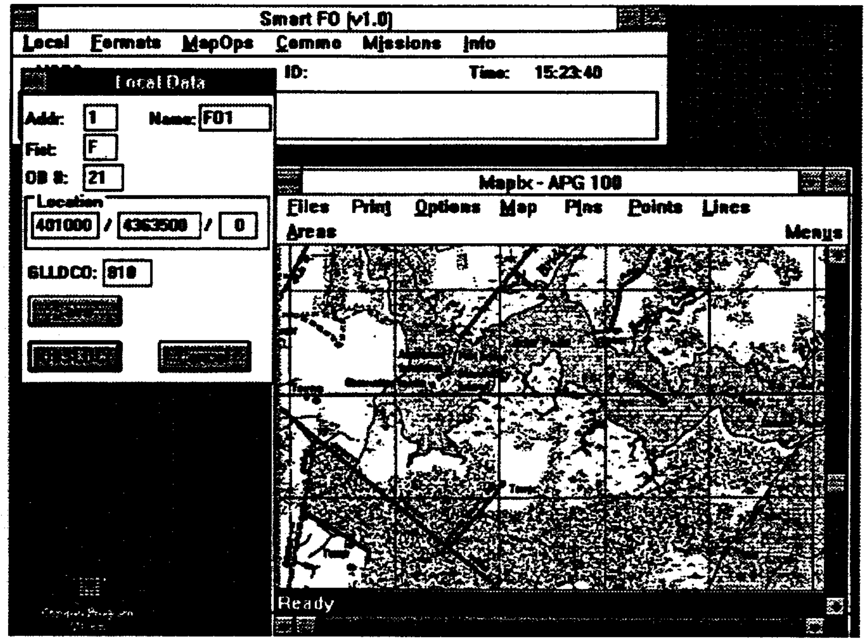

Figure A–3: SMART FO Local Data Input Dialog

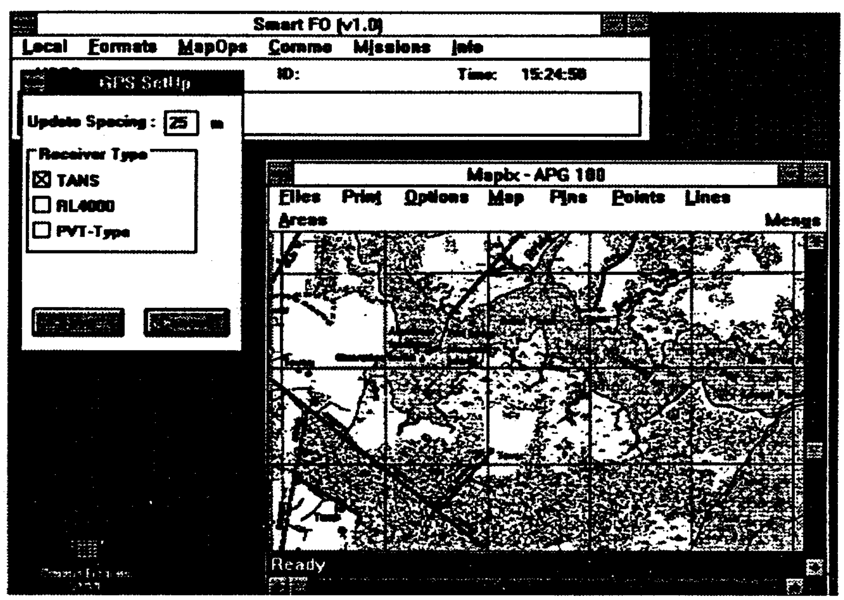

Figure A–4: SMART FO GPS Type Selection Dialog

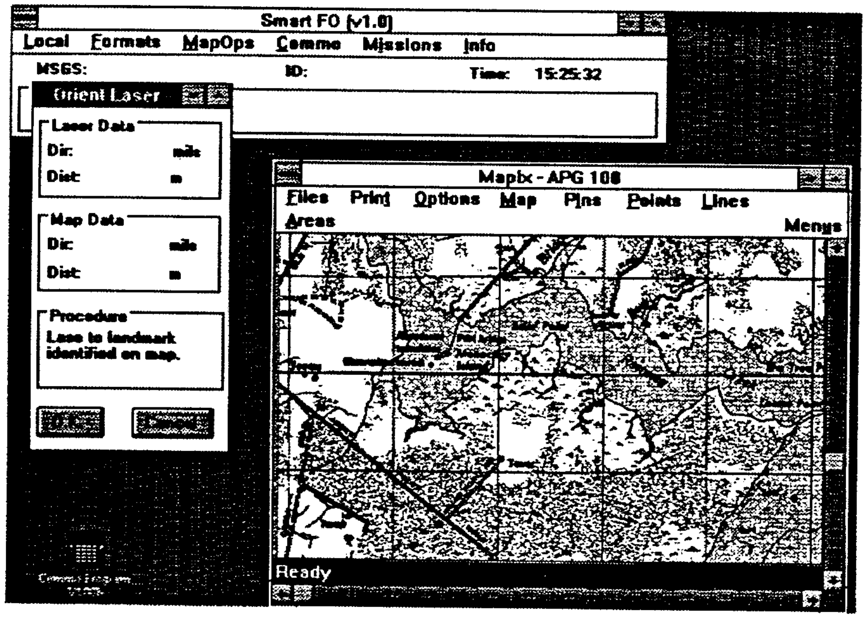

Figure A–5: SMART FO Laser Orient Dialog

A–4. Digital Message Device Message Formats

Figure A–6 shows the DMD message formats available in the SMART FO. There is no reason to use these, but they are provided for historical reasons. Figure A–7 shows a SMART FO FRGRID message dialog. The user can input data as appropriate or use the defaults. Pressing the SEND button will transmit the message to the FIST or howitzer, initiating a fire mission.

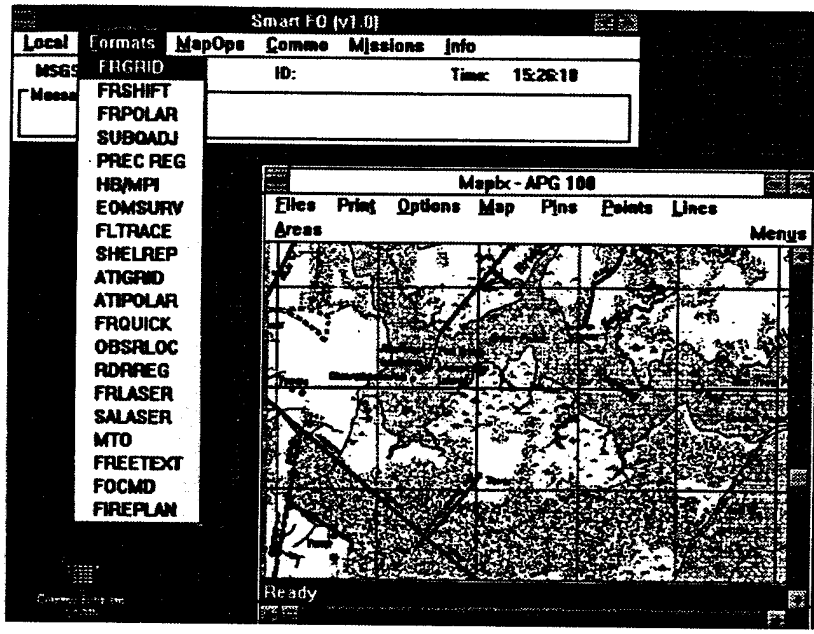

Figure A–6: SMART FO DMD Message Formats Menu

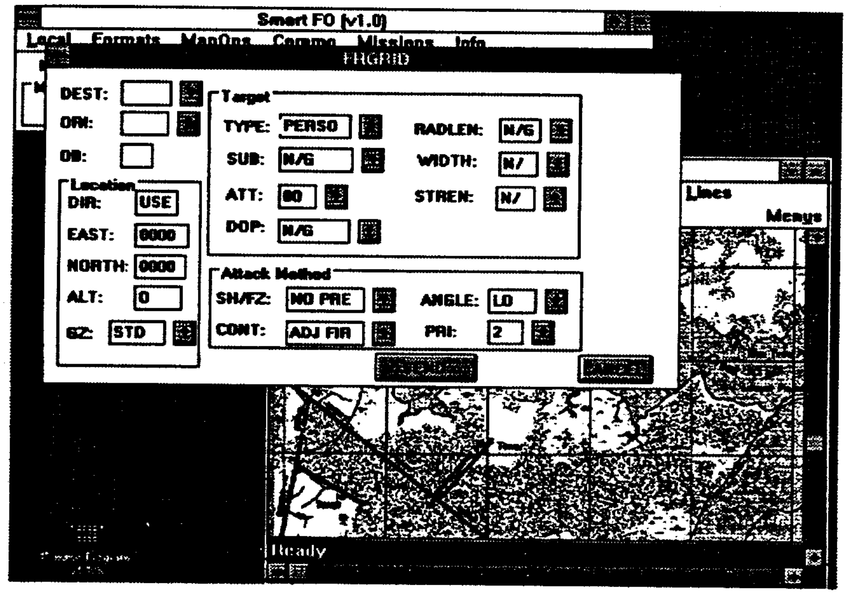

Figure A–7: SMART FO FRGRID Message Format Dialog

A–5. Map Operations

The SMART FO provides the capability to control the visibility of objects on the digital map, perform coordinate transformations, and initialize and terminate map operations.

Upon startup, the user should initialize the map. This is performed by pressing Initialize on the MapOps menu. This will initiate the data communications between the program executive and MAPIX, and add objects to the map which are currently stored in the SMART FO Subscriber Table.

Figure A–9 shows the Overlay popup. An overlay is defined in the SMART FO as a collection of objects which are visible on the map at the same time. An object can belong to more than one overlay. The user uses the Add option to add an object to the map. The (Del)ete option removes an object from map, the Purge command removes an object from the current overlay, PurgeAll removes all objects from the overlay, Show turns the Overlay visibility on, Hide turns the Overlay visibility off, and Cancel closes the Overlay popup.

Figure A–10 shows the UTM–>Lat/Lon coordinate Conversion dialog box. This dialog is used to convert UTM coordinates to Lat/Lon using the appropriate map Datum and Gridzone. The SMART FO also provides the capability to perform the reverse operation.

Figure A–11 depicts the MAPMOD dialog. The data entered here are the location of the known point on the digital map and the Gridzone of the digital map.

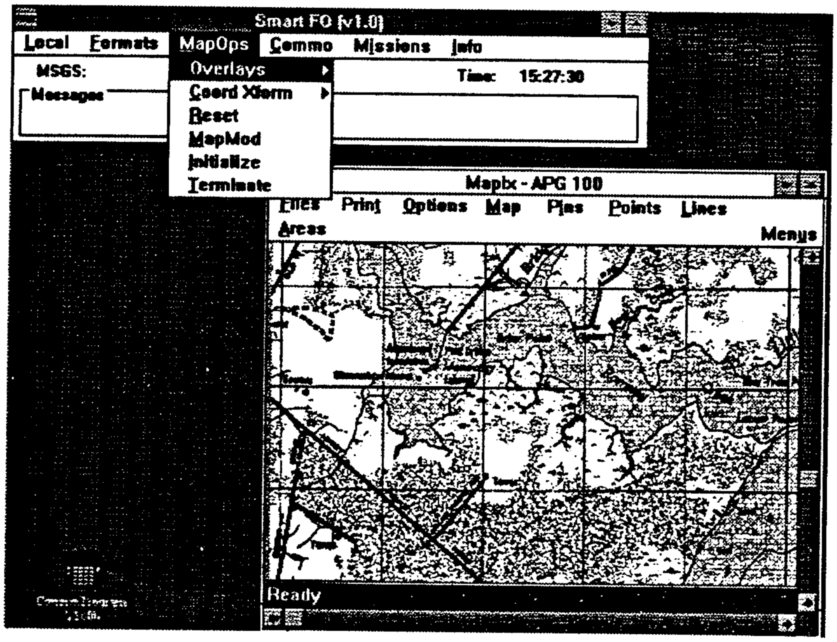

Figure A–8: SMART FO Map Operations Menu

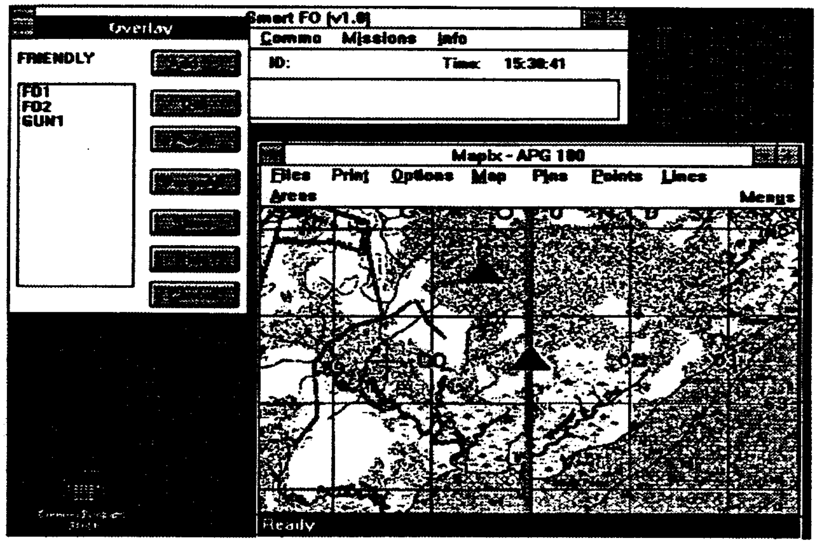

Figure A–9: SMART FO Map Overlay Dialog

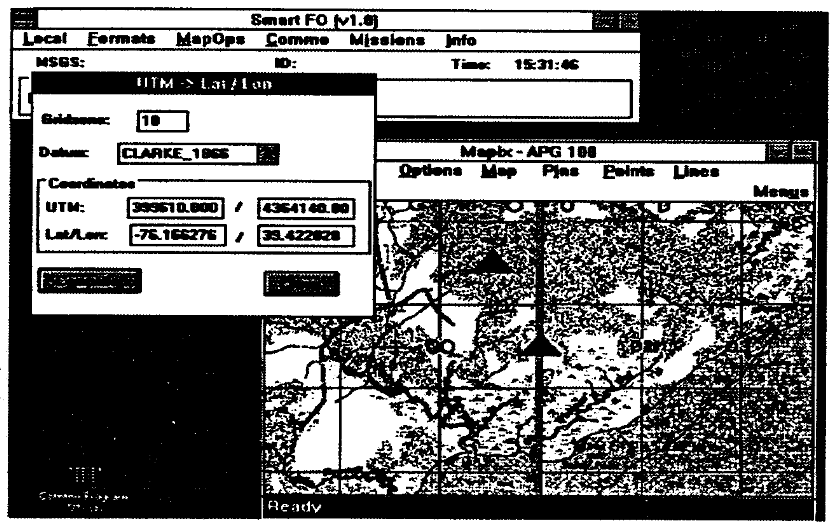

Figure A–10: SMART FO Map Coordinate Conversion Dialog

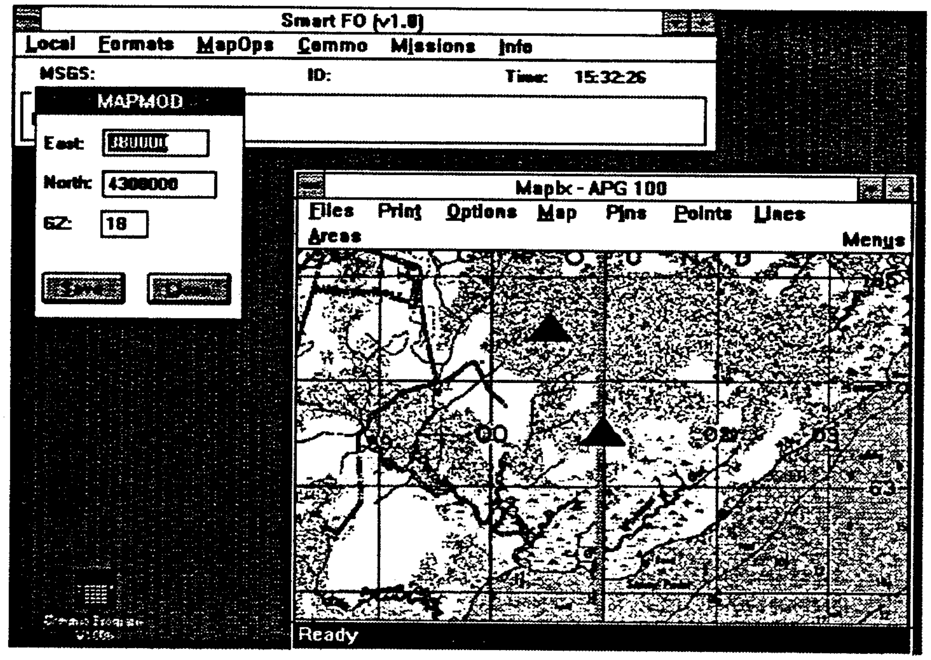

Figure A–11: SMART FO Map Mod Input Dialog

A–6. Communications Control

This menu is used to control the communication program, COMMO. Upon startup, the user must start the communications program to begin sending and receiving digital data. This is done by pressing the Start CommProg option in the Commo menu. After the COMMO program has started and initialized the communications ports, press Initiate. This starts the flow of data between the program executive and the COMMO program. Terminate stops data transmission between the two programs.

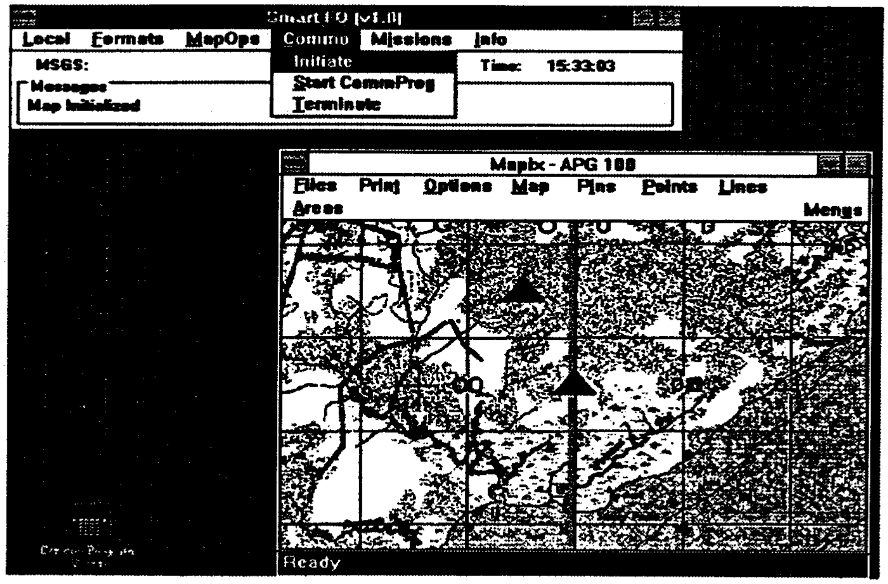

Figure A–12: SMART FO Communications Menu

A–7. Fire Mission Execution Windows

Figure A–13 shows the Fire Mission menu. The user can select the type of mission to run, Adjust Fire, Fire–For–Effect, Moving Target Fire–For–Effect, Moving Target Time–On–Target, or Time–On–Target or Multiple Round/Simultaneous Impact (MRSI).

Figure A–14 shows the Adjust Fire Mission window. Target data are entered either by entering from the keyboard, clicking a location on the digital map, or lasing a position. The window contains a status field, a target number field, and a Time–Of–Flight (TOF) field. The Status field displays the current mission state (FRLASER, MTO, SHOT, SPLASH, EOM). The TOF field displays the time–of–flight of the round as received in the Message–To–Observer (MTO) message. When an FO Command SHOT message is received, the TOF counts down from the TOF to zero. The controls on the window allow the user to start the mission, perform an adjust phase, a fire–for–effect phase, and end the mission. The CHECKFIRE button sends an FO Command CHECKFIRE message to the howitzer. The MSN DATA button displays a dialog for the input of target info, destination and origin address, and mission control data. These buttons are included in all mission windows.

Figure A–15 shows the Fire–For–Effect (FFE) Mission windows. It is similar to the Adjust Fire Mission window except it only contains Start mission and End mission controls.

Figure A–16 shows the Moving Target Fire–For–Effect Mission window. The Moving Target FFE mission allows the FO to place multiple volleys of fire onto a moving target. The Window contains controls to select the current target tack, transmit the predict point and fall of shot time, compute a predict point, and end the mission. The mission window processes target speed and direction from

the user's target lasings, updates the predict point on the digital map, and formats the digital message for transmission.

Figure A–17 shows the Moving Target Time–On–Target (TOT) Mission window. This mission is used to put multiple rounds onto a moving target simultaneously. The user starts the mission by pressing the Start button and lases the target to get a good target speed. When the predict point looks good to the observer, Xmit Target is pressed. This sends the predict point and fall–of–shot time to the howitzer. The howitzer computes the appropriate trajectories for a three– or four–round MRSI mission on the predict point and fires the mission.

Figure A–18 shows the Time–On–Target Mission window. This mission places multiple rounds on a location simultaneously. The mission is initiated by the FO by lasing a position with the laser or clicking a position on the map. Pressing Start sends the FRLASER digital message to the howitzer to begin processing. After receiving the MTO, the user presses Fire to fire the mission. The howitzer fires the rounds in the proper sequence to land on target at the same time.

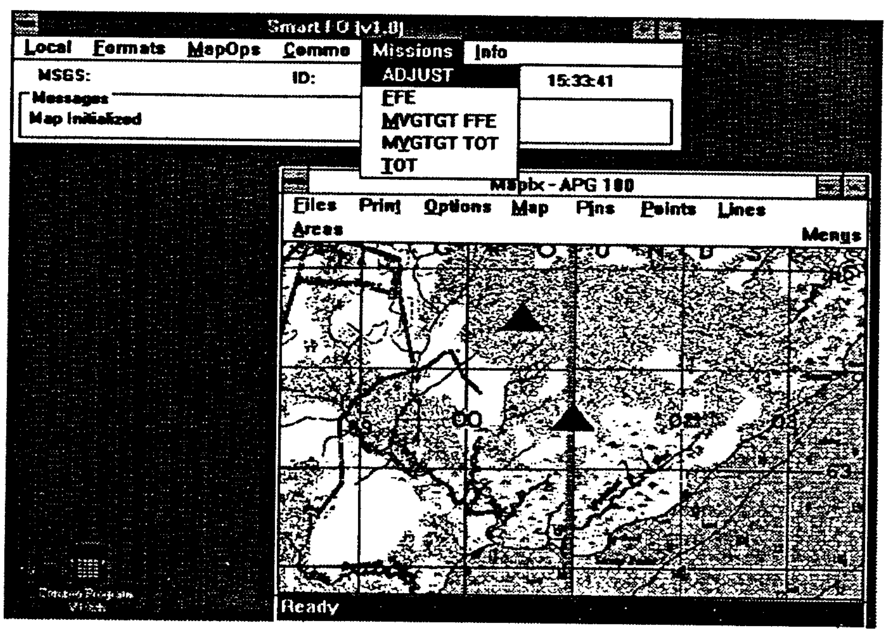

Figure A–13: SMART FO Fire Missions Menu

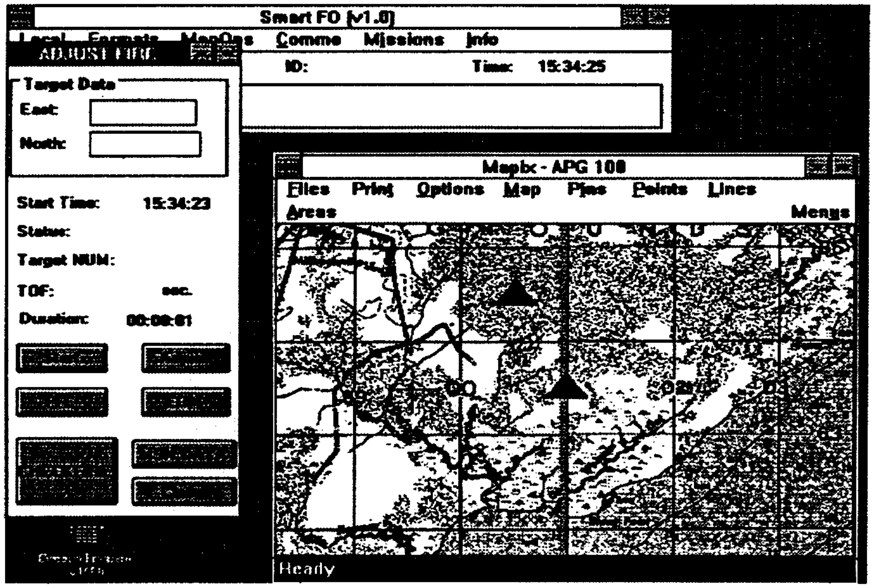

Figure A–14: SMART FO Adjust Fire Mission Dialog

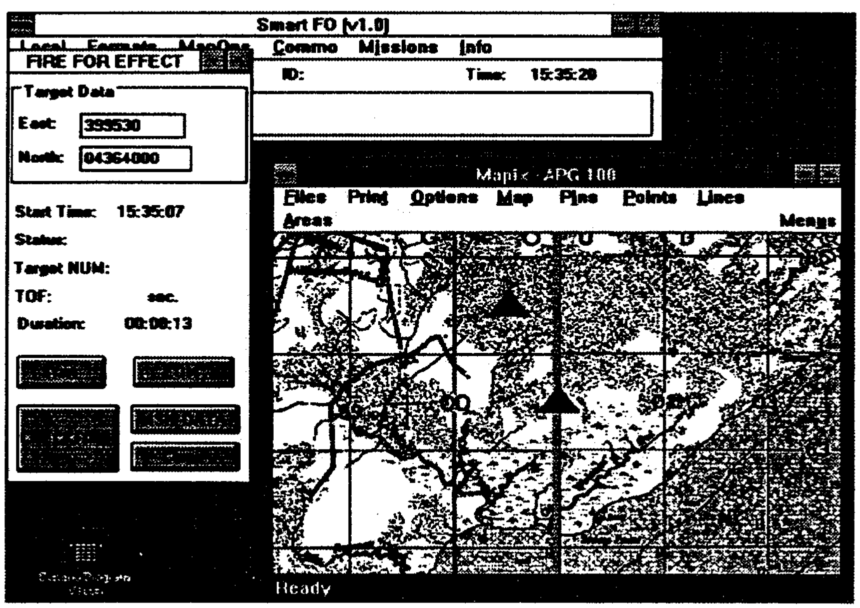

Figure A–15: SMART FO Fire–For–Effect Mission Dialog

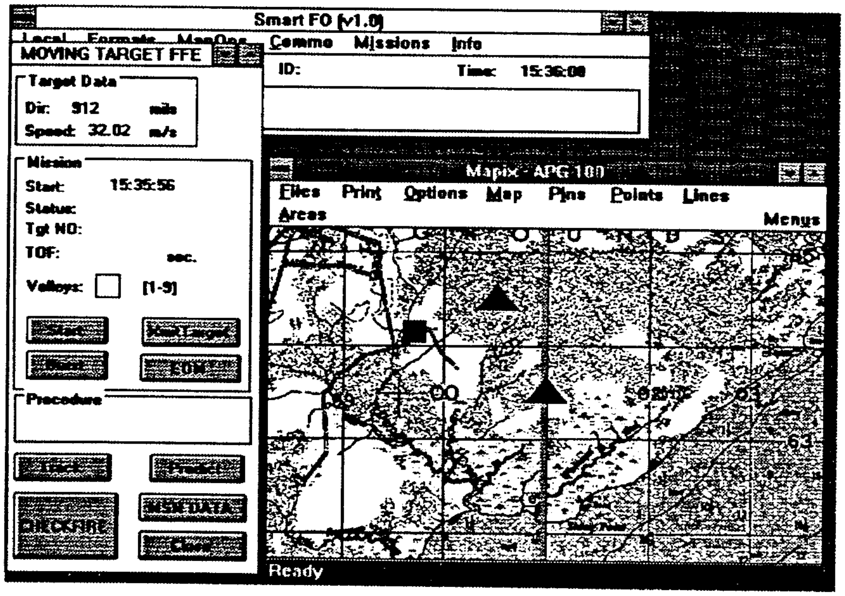

Figure A–16: SMART FO Moving Target Fire–For–Effect Mission Dialog

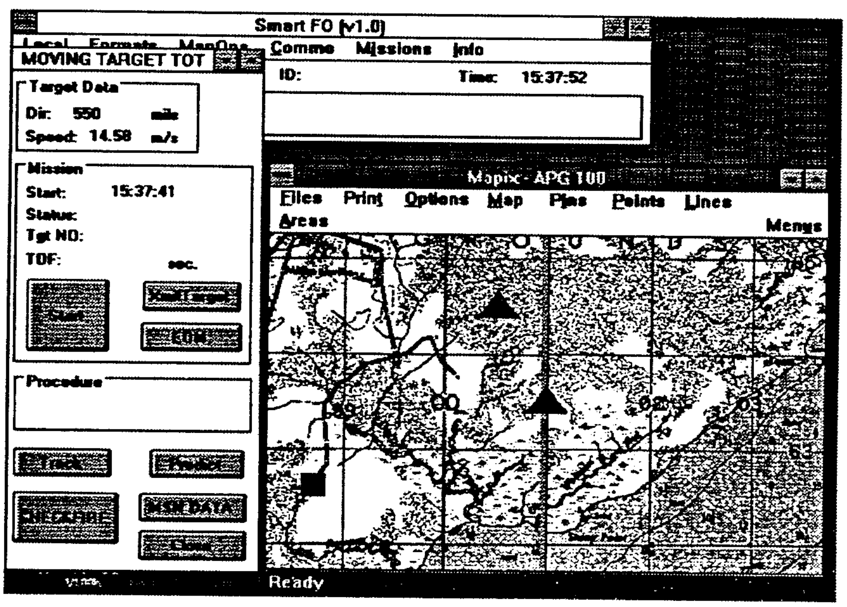

Figure A–17: SMART FO Moving Target Time–On–Target (MRSI) Mission Dialog

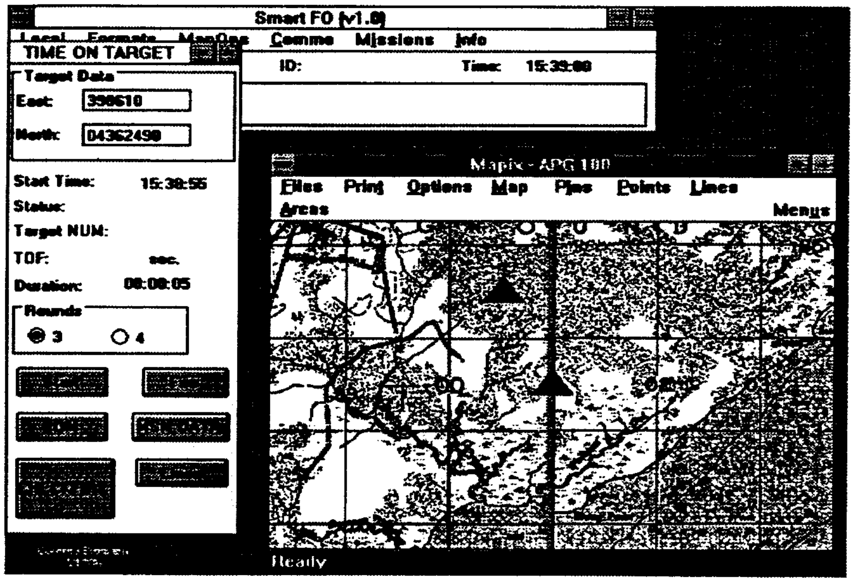

Figure A–18: SMART FO Time–On–Target (MRSI) Mission Dialog

A–8. SMART FO Info

The Info menu provides access to the Received message queue, Subscriber Table, and Mission Defaults dialog.

The received message queue displays a listing of messages received, and the user can view them as necessary.

Figure A–20 shows the subscriber data dialog. The Subscribers menu item displays a listing of subscribers, and the user can add subscribers as necessary. The MAPIT control adds the subscriber's Icon to the map, and the PING button sends a FREETEXT message to the user.

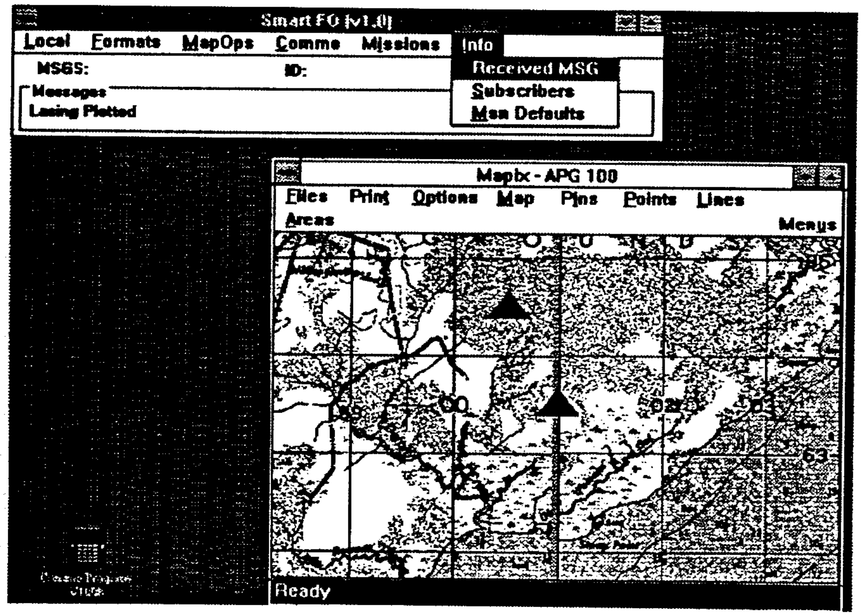

Figure A–19: SMART FO Info Menu

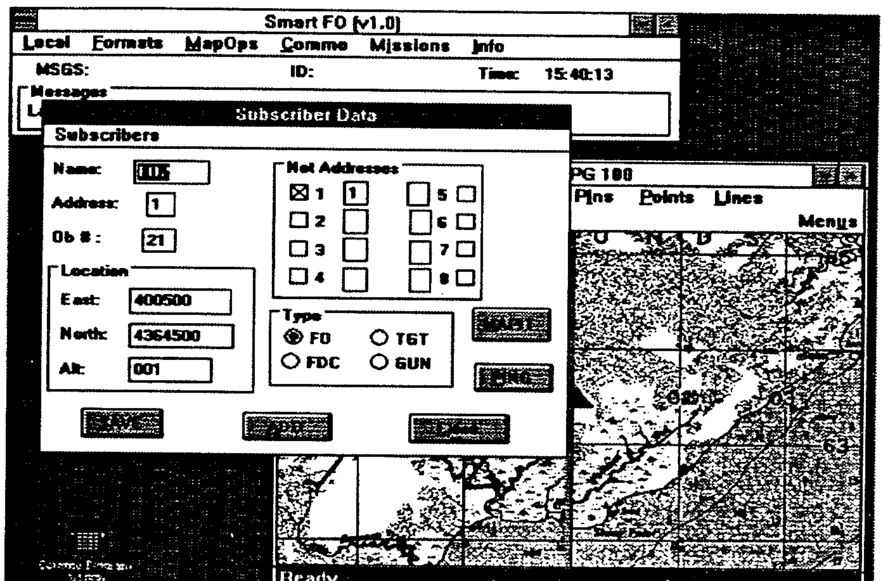

Figure A–20: SMART FO Subscriber Data Entry Dialog

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